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Effects of aquaculture on migration and movement patterns of double-crested cormorants

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Abstract: We analyzed 10,620 recovery records for double-crested cormorants (*Phalacrocorax auritus*) banded as nestlings from 1923 to 2006 to determine the population's age structure, migration routes, dispersal patterns, and the possible influence of the expansion of the aquaculture industry in the southeastern United States on these population characteristics. Ninety-nine percent of the birds were banded during June to August, and 78% were banded as pre-fledged birds. Cormorants banded in the interior region of the United States comprised 91% of all birds banded from 1955 to 2006; these birds wintered primarily in the Lower Mississippi Valley and the northern Gulf of Mexico area. From 1986 to 2006, the number of bands recovered in principal aquaculture areas in the southeastern United States increased 454%, while the number of bands recovered in other areas increased 55%. Further, pre-aquaculture expansion (1923–1985) birds were recovered at greater distances from their banding colonies than were post-aquaculture epansion (1986–2006) birds. These data indicate that the expansion of southeastern aquaculture has influenced double-crested cormorant movements and migration patterns.

Key words: aquaculture, banding, double-crested cormorant, human–wildlife conflicts, migration, movements, *Phalacrocorax auritus*

Since the 1970s, double-crested cormorant (*Phalacrocorax auritus*) numbers have steadily increased throughout most of their breeding range (Weseloh et al. 1995, Price and Weseloh 1986). Although cormorant populations breeding in the Atlantic and western regions of the United States are declining, cormorant populations breeding in the Mississippi Flyway, particularly the Great Lakes, are experiencing rapid growth (Weseloh et al. 1995, Sauer et al. 1997, Tyson et al. 1999). Current population estimates of double-crested cormorants are lacking; however, Tyson et al. (1999) estimated the North American population at 1 to 2 million birds.

Concomitant with increasing cormorant numbers, the channel catfish (*Ictalurus punctatus*) aquaculture industry in the southeastern United States began to rapidly expand after 1985 (Mott and Brunson 1997), increasing production from 34,000,000 kg to 218,000,000 kg live weight of catfish processed in 2008 (U.S. Department of Agriculture 2008). Of 15 catfish-producing states, Alabama, Arkansas, Louisiana, and Mississippi increased their pond area of production from about 28,000 ha in 1987 to >53,000 ha in 2008 (U.S. Department of Agriculture 2008).

Numbers of cormorants that wintered in the Lower Mississippi Valley also increased dramatically during the 1970s and 1980s (Alexander 1977–1990). In the delta region of Mississippi, cormorant numbers increased from approximately 32,000 to 64,000 birds between 1995 and 1999 (Glahn et al. 2000). In the early 1990s, Glahn and Brugger (1995) estimated that cormorants wintering in the delta region of Mississippi cost catfish farmers approximately $2 million annually in revenues due to cormorants eating the fish. However, Glahn et al. (2000) estimated that these increasing numbers of cormorant cost Mississippi catfish producers up to $25 million annually by the late 1990s.

In an earlier analysis of double-crested cormorant band recoveries, Dolbeer (1991)

found that birds nesting in both the northern United States and Canada from Alberta to the Gulf of St. Lawrence wintered primarily in the southern United States between Texas and Florida. Up to 70% of birds from Saskatchewan through the Great Lakes area and 10% of birds from other areas were recovered in the lower Mississippi Valley (Dolbeer 1991). Duffy (1995), Weseloh and Ewins (1994), and Glahn et al. (1999) have suggested that the expansion of the aquaculture industry in the Lower Mississippi Valley may have caused cormorants to shift their migratory paths to this area, leading to improved overwinter survival, thus contributing to the dramatic increase in their numbers.

A more thorough understanding of the movements and wintering areas used by double-crested cormorants is necessary to develop effective methods to manage their impact on the aquaculture industry. The objectives of this study were to analyze double-crested cormorant band recovery information to (1) determine the age structure and causes of mortality (i.e., recovery circumstances) of banded birds, (2) determine the banding colony location of recoveries from southeastern aquaculture areas, and (3) evaluate the potential effect of the expansion of the aquaculture industry in the southeastern United States on double-crested cormorant migration and wintering patterns.

Methods

Recovery data for double-crested cormorants banded from 1923 to 2006 and banding summary data from 1955 to 2006 (numbers of birds banded were first recorded in 1955) were provided by the U.S. Geological Survey, Biological Resources Division, Bird Banding Laboratory, Laurel, Maryland. Only recoveries of nestlings or pre-fledged birds banded at breeding colonies were used for analyses of distances moved from the breeding colonies to recovery locations or for age structure. Also, records without the accurate month, or location of recovery, or recoveries <13 km from their natal colony were not analyzed for distances moved from the breeding colonies to recovery locations or for age structure. We used ArcView 3.1 (Environmental Systems Research Institute, Redlands, Cal., 1998) to plot recovery locations by banding regions as described by Tyson et al. (1999).

We also analyzed recovery data (by banding and recovery regions) for changes before and after the expansion of the aquaculture industry in the southeastern United States (1923–1985 and 1986–2006). For this study, we defined the southeastern United States as Alabama, Arkansas, Louisiana, and Mississippi. Prior to analyzing recoveries by pre- and post-aquaculture expansion, we evaluated the band recovery data relative to the number of birds banded per period. We calculated a 95% confidence interval (CI) about the mean annual ratio of band recoveries to the number of birds banded from 1955 to 1985, then compared the corresponding mean annual ratio for 1986 to 2006 within region. We used a 2-way ANOVA with the Bonferroni option to evaluate the mean distance from banding to recovery location for birds banded as pre-fledglings and recovered from December to February (Proc GLM, SAS 1994). Because birds were banded almost exclusively in the Great Lakes area during the post-aquaculture period, distances moved were compared between pre- and post-aquaculture expansion (1923–1985 and 1986–2006, respectively) for this banding area only. For this analysis, we compared 4 age groups (0, 1, 2, and ≥3 years), based on the birds' age when recovered. Fixed effects were the period of recovery (pre- versus post-aquaculture expansion), recovery age, and the pre- and post-aquaculture expansion age group interaction. For all analyses, we assumed that the probability of recovery was equal among locations.

Results

Of the 10,620 cormorant band recoveries from 1923 to 2006, 99% of the birds were banded in the months of June, July, or August; 78% were banded as pre-fledged birds; and 22% were banded as fledged, unknown age, or adult birds (Table 1). From 1955 to 2006, the band-recovery rate was 6.0%. Eighty-two percent and 73% (1923–1985 and 1986–2006, respectively) of the birds recovered were reported as found dead, shot, caught in nets or traps, or collected for scientific purposes. The percentage of birds reported as shot decreased, while the percentage of scientific collections increased after 1985 (Table 2). Recoveries of cormorants banded in the Atlantic and interior regions

Table 1. Age and month of banding for 10,620 double-crested cormorants recovered from July 1923 to August 2006.

	Age at Banding				
Month of banding	Pre-fledged	Hatching year	Unknown	Adult	Total recovered
June	3,916	574	46	42	4,578
July	4,117	1,152	182	15	5,466
August	264	174	34	2	474
Other months	31	18	6	47	102
Total	8,328	1,918	268	106	10,620

Table 2. Comparison of the distribution of 10,620 double-crested cormorant band recoveries from 1923 to 1985 and 1986 to 2006 by "how-obtained" codes used by the U.S. Bird Banding Laboratory. Birds with codes 50, 56, 96, or 98 were excluded from other analyses.

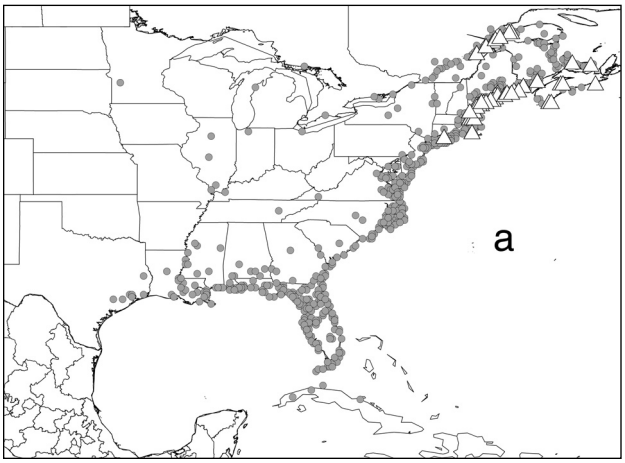
How-obtained code number[a]	Definition	No. of recoveries (% of total recoveries)		
		1923–1985	1986–2006	Total
0, 21, 30, 44, 45	Found dead	1,824 (36)	3,241 (57)	5,065 (48)
1, 91	Shot	1,504 (30)	249 (4)	1,756 (16)
4, 17, 26	Nets, fishing gear, traps, or drowned	765 (15)	608 (11)	1,373 (13
29, 52, 33, 52, 87–89, 99	Sight record	194 (4)	184 (3)	378 (4)
16, 53	Scientific collection	11 (<1)	419 (7)	430 (4)
50, 56, 96, 98	Skeleton found or no information	447 (9)	477 (9)	924 (9)
Other codes	Misc. (e.g., injury, dead on highway)	237 (5)	457 (8)	694 (6)
Total		4,985	5,635	10,620

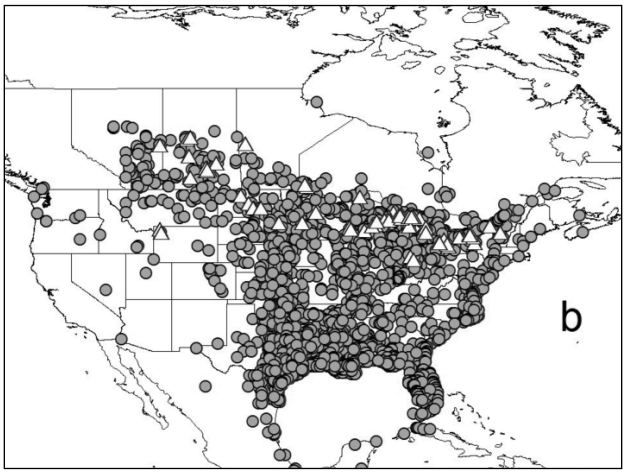
[a]Gustafson et al. 1997

of the United States overlapped along the Atlantic coast and northeastern Gulf of Mexico (Figure 1a, b). Cormorants banded in the interior region wintered primarily in the Lower Mississippi Valley and the northern Gulf of Mexico (Figure 1b). Only 2 cormorants banded in the western region were recovered east of the Rocky Mountains: one in Lake Huron and one in Indiana (Figure 1c). Of the 175 cormorants banded in the southeastern region, only 21 birds were recovered in Florida and along the Atlantic and Gulf of Mexico coasts.

The mean annual ratio of cormorants banded to the number of recoveries by region (between pre- and post-aquaculture expansion, 1955 to 1985 and 1986 to 2006, respectively) was similar

for the Atlantic and western populations, but decreased for the interior population (Table 3). After 1985, there was a 454% increase in the number of bands recovered in principal southeastern aquaculture areas, while the number of bands recovered in other areas increased 55% (Table 4). Further, there was a 523% increase in the number of birds recovered in principal southeastern aquaculture areas that were banded in the interior region during the period of aquaculture expansion after 1985 (Table 4). The total number of cormorants banded increased for all but the Atlantic region after 1985 (Table 5). Cormorants banded in the interior region comprised 91% of the birds banded from 1955 to 2006. Of the 1,549 recoveries made in principal southeastern aquaculture areas (1931–2006), 96% were banded in the interior region. The banding locations of cormorants recovered in principal southeastern aquaculture areas from 1931 to 1985 were distributed from Maine, Massachusetts, and Quebec (10%), throughout the northern Great Lakes (44%), and along the northern Great Plains (46%). Since 1986 however, 95% of the banding locations of cormorants recovered in principal southeastern aquaculture areas were concentrated in lakes Huron, Michigan, Ontario, and Lake of the Woods (Figure 2).





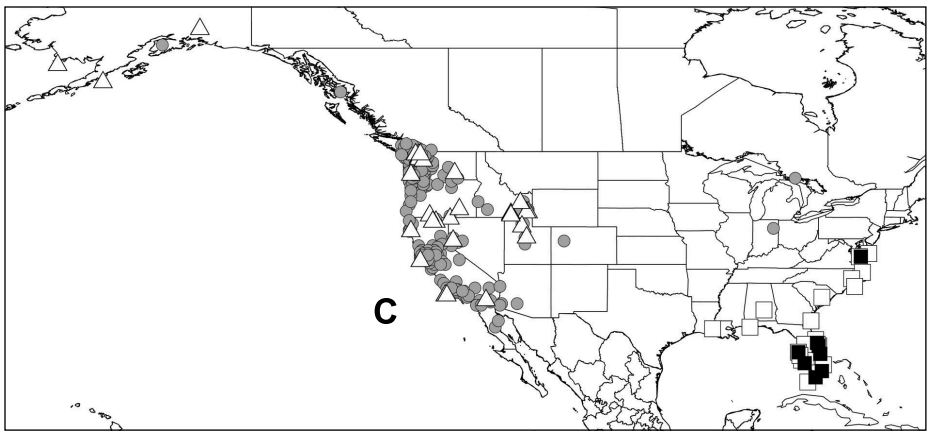


Figure 1a, b, c. Banding (triangles) and recovery (circles) locations of double-crested cormorants for the (a) Atlantic, (b) interior, and (c) western regions from 1923 to 2006. Southeastern region (c) banding locations (filled squares) and recovery locations (open squares).

For birds banded in the Great Lakes area as pre-fledglings and recovered during December to February, distances moved pre- and post-aquaculture expansion differed ($F_{1,789}=4.47$, $P=0.03$); pre-aquaculture birds were recovered

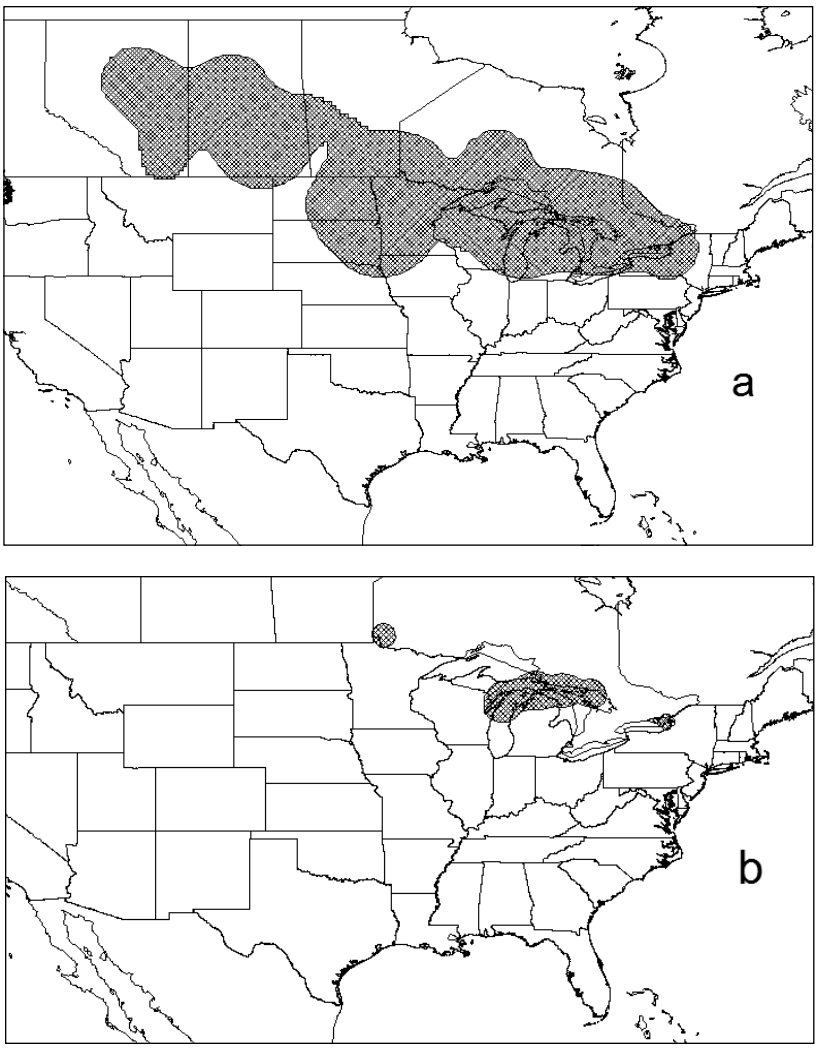


Figure 2a, b. Banding locations (hatched areas) of 95% of double-crested cormorant recoveries near principal southeastern aquaculture facilities for (a) 1955 to 1985 and (b) 1986 to 2006.

at greater distances from their banding colonies than were post-aquaculture birds ($\bar{x}$ = 1,654 ± 449 km [SD], n = 118 and $\bar{x}$ = 1,556 ± 717 km, n = 679, respectively). Recovery distances were similar ($F_{3, 789}$ = 1.88, P = 0.13) across cormorant age classes. The mean recovery distances pre- and post-aquaculture expansion × recovery age interaction were also similar ($F_{3, 789}$ = 0.86, P = 0.46). Nonbreeding birds (assuming breeding at age ≥3 years) comprised 80.7% of band recoveries from 1930 to 1985 and 59.8% from 1986 to 2006 (Table 6).

Discussion

The percentage of pre-fledged birds banded during summer months was similar to that described by Dolbeer (1991). Our overall recovery rate of 6.0% was larger than the 3.3% return rate of ≤4-year-old old birds banded in 1986 at Little Galloo Island, New York (Weseloh and Ewins 1994). Possible reasons for the decrease in number of birds reported as shot after 1985 may have been the reluctance of some individuals to report a protected bird as shot due to fear of prosecution (Strait and Sloan 1975) or confusion regarding the proper reporting procedure for birds legally killed under the recently-enacted Cormorant Depredation Order (U.S. Fish and Wildlife Service 1998, Glahn et al. 2000). The increase in the number of birds reported as scientific collections likely reflected an increase in cormorant collections

Table 3. Ninety-five percent confidence limits (CL) about the mean annual ratio of band recoveries to number of banded double-crested cormorants available for recovery (i.e., birds banded within a region to birds recovered through each respective year[a]) for periods before (1960–1985) and after (1986–2006) the expansion of the aquaculture industry (see Tyson et al. 1999). Consistent banding and reporting data prior to 1960 were available only for the interior region; we do not report those data here, though they are reflected in the ratio of recovery:availability for 1960, as described in narrative.

Region	Period	Birds banded	Lower CL	$\bar{\times}$	Upper CL
Western	1960–1985	3,405	0.009	0.013	0.017
	1986–2006	180	0.025	0.044	0.063
	1960–2006	3,585	0.017	0.027	0.037
Interior	1960–1985	71,214	0.007	0.014	0.021
	1986–2006	86,741	0.004	0.005	0.006
	1960–2006	15,8198	0.006	0.010	0.014
Atlantic	1960–1985	8,545	0.008	0.011	0.015
	1986–2006	3,591	0.005	0.006	0.008
	1960–2006	12,136	0.007	0.009	0.011

[a]Ratio reflects an annual survival rate of 90%.

Table 4. Number (% change) of double–crested cormorants recovered within and outside of principal southeastern aquaculture areas before and after 1985 by Atlantic, Interior, West, and Southeast (SE) banding regions (see Tyson *et al*. 1999). Bands recovered outside of these regions are not represented.

Period	Banding region location									
	Atlantic	(% +/–)	Interior	(% +/–)	West	(% +/–)	SE	(% +/–)	Total	(% +/–)
Before 1985, within aquaculture	32		205		0		0		237	
After 1985, within aquaculture	31	(–3)	1,278	(+523)	0	(0)	3		1,312	(+454)
Total	63		1,483		0		3		1,549	
Before 1985, outside aquaculture	645		1,355		483		4		2,487	
After 1985, outside aquaculture	340	(–47)	3,273	(+141)	215	(–55)	14	(+250)	3,842	(+55)
Total	985		4,628		698		18		6,329	

Table 5. Number (% change) of pre-fledged double–crested cormorants banded <1985 and >1986 by Atlantic, Interior, West, and Southeast (SE) regions (see Tyson *et al*. 1999). Banding summary data was not available before 1955.

Period	Banding location by region									
	Atlantic	(% +/–)	Interior	(% +/–)	West	(% +/–)	SE	(% +/–)	Total	(% +/–)
Pre-1985	8,545		71,457		3,411		60		83,473	
Post-1985	3,591	(–58)	86,751	(+21)	175	(–95)	115	(+92)	90,632	(+9)
Total	12,136		158,208		3,586		175		174,105	

Table 6. The age structure of all double–crested cormorant band recoveries for 1930 to 1985 and 1986 to 2006 (n = 7,868).

Age at recovery	1930–1985		1986–2006		Total	
	No. recovered	%	No. recovered	%	No. recovered	%
0	1,196	44	1,629	32	2,825	36
1	712	26	1,043	20	1,755	22
2	292	11	402	8	694	8.8
≥3	524	19	2,070	40	2,594	33
Total	2,724	100	5,144	100	7,868	100

for diet studies since 1985 (Campo et al. 1993, Glahn et al. 1995, Glahn et al. 1998).

The ratio of birds banded to the number of birds recovered decreased for the interior region during 1986 to 2006 compared to those recovered during 1955 to 1985. Although the number of birds banded and overall bands recovered in the interior region during post-aquaculture expansion increased, possible higher survival (Glahn et al. 1999) may in part explain the decline in proportion of banded cormorants recovered during the post aquaculture period. The increase in the number of birds banded within the interior region and recovered within principal southeastern aquaculture areas was much greater than the increase in the number of birds banded in the interior region for the same period (Table 5). However, recoveries of birds outside principal southeastern aquaculture areas after 1985 that were banded in interior region colonies increased by a much smaller amount.

The reasons for the increase in the number of bands recovered in principal southeastern aquaculture areas after 1985 may be due to several factors. For example, cormorants may have been attracted to aquaculture facilities because of the availability of readily-accessible food and thereby increased their overwinter survival (Weseloh and Ewins 1994, Duffy 1995, Glahn et al. 1999). Another possibility is that more bands may have been recovered in southeastern aquaculture areas due to increased human activity and increased take under depredation permits in these areas since 1985 (Belant et al. 2000). Also, the distribution of colonies where cormorants were banded were widespread from 1955 to 1985, but banding

became more concentrated in the Great Lakes area after 1985. This may have contributed to increased recoveries in southeastern aquaculture areas.

Although both wear and loss of aluminum bands may result in an underestimation of the proportion of older age-class recoveries in a population (Coulson and White 1955, Coulson 1976, Nelson et al. 1980, Ryder 1981, Coulson and Butterfield 1986,) similar types of bands were used during both periods. Therefore, the rate of band wear and loss should have been similar during both periods. We noted a marked decrease in recoveries of cormorants <3 years old after 1985. Our analysis revealed no period × recovery age interaction nor evidence of disproportionate use of aquaculture areas by older birds. Hence, reasons for the decrease are unclear. However, during 1986 to 2006, nearly all southeastern aquaculture cormorant recoveries were from the interior region, with 57% <3 years old (i.e., sub-adult) at recovery, and only 17% were age <1. Further, Glahn (personal communication) found that sub-adults comprised 35 to 50% of the cormorants collected for food-habits studies in the delta region of Mississippi during the winters of 1989 to 1990 and 1990 to 1991. Sub-adult cormorants may be more naïve than adults, and, thus, are more likely to be killed and recovered at these sites.

These data indicate that cormorant band recoveries have increased at a much higher rate in southeastern aquaculture areas than elsewhere. We concur with Weseloh and Ewins (1994), Duffy (1995), and Glahn et al. (1995) that the expansion of the aquaculture industry after 1985 has contributed to changes in cormorant migration and wintering patterns and has concentrated wintering populations in primary aquaculture areas of the southeastern United States.

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Literature cited

Alexander, E., Jr. 1977–1990. Washington County (south) Mississippi (CBC). American Birds 31:657; 32:666; 33:510; 35:555; 36:582; 37:593; 38:623; 39:616; 40:811; 41:924-927; 42:853; 43:896; 44:774.

Belant, J. L., L. A. Tyson, and P. A. Mastrangelo. 2000. Effects of lethal control at aquaculture facilities on populations of piscivorous birds. Wildlife Society Bulletin 28:379–384.

Campo, J. J., B. C. Thompson, J. C. Barron, R. C. Telfair II, P. Durocher, and S. Gutreuter. 1993. Diet of double-crested cormorants wintering in Texas. Journal of Field Ornithology 64:135–144.

Coulson, J. C. 1976. An evaluation of the reliability of rings used on herring and lesser black-backed gulls. Bird Study 23:21–26.

Coulson, J. C., and J. Butterfield. 1986. Studies on a colony of colour-ringed herring gulls *Larus argentatus*: I. Adult survival rates. Bird Study 33:51–54.

Coulson, J. C., and E. White. 1955. Abrasion and loss of rings among sea-birds. Bird Study 2:41–44.

Dolbeer, R. A. 1991. Migration patterns of double-crested cormorants east of the Rocky Mountains. Journal of Field Ornithology 62:83–93.

Duffy, D. C. 1995. Why is the double-crested cormorant a problem? Insights from cormorant ecology and human sociology. Colonial Waterbirds 18:25–32.

Glahn, J. F., and K. E. Brugger. 1995. The impact of double-crested cormorants on the Mississippi delta catfish industry: a bioenergetics model. Colonial Waterbirds 18:158–167.

Glahn, J. F., P. J. Dixon, G. A. Littauer, and R. B. McCoy. 1995. Food habits of double-crested cormorants wintering in the Delta Region of Mississippi. Colonial Waterbirds 18:168–175.

Glahn, J. F., J. B. Harrel, and C. Vyles. 1998. The diet of double-crested cormorants feeding at lakes in the southeastern United States. Colonial Waterbirds 21:446–452.

Glahn, J. F., D. S. Reinhold, and C. A. Sloan. 2000. Recent population trends of double-crested cormorants wintering in the Delta Region of Mississippi: responses to roost dispersal and removal under a recent depredation order. Waterbirds 23:38–44.

Glahn, J. F., M. E. Tobin, and J. B. Harrel. 1999. Possible effects of catfish exploitation on over-

winter body condition of double-crested cormorants. Pages 107–113 *in* M. E. Tobin, editor. Symposium on double-crested cormorants: population status and management issues in the Midwest. U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Technical Bulletin 1879. Washington, D.C., USA.

Mott, D. F., and M. W. Brunson. 1997. A historical perspective of catfish production in the Southeast in relation to avian predation. Proceedings Eastern Wildlife Damage Management Conference 7:23–30.

Nelson, L. J., D. R. Anderson, and K. P. Burnham. 1980. The effect of band loss on estimates of annual survival. Journal of Field Ornithology 51:30–38.

Price, I. M., and D. V. Weseloh. 1986. Increased numbers and productivity of double-crested cormorants, *Phalacrocorax auritus*, on Lake Ontario. Canadian Field-Naturalist 100:474–482.

Ryder, R. A. 1981. Movements and mortality of white pelicans fledged in Colorado. Colonial Waterbirds 4:72–76.

Sauer, J. R., J. E. Hines, G. Gough, I. Thomas, and B. G. Peterjohn. 1997. The North American breeding bird survey results and analysis. Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Strait, L. E., and N. F. Sloan. 1975. Movements and mortality of juvenile white pelicans from North Dakota. Wilson Bulletin 87:54–59.

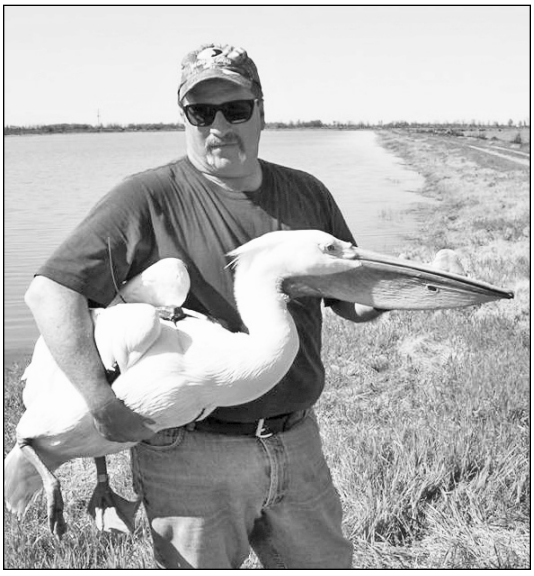
Tyson, L. A., J. L. Belant, F. C. Cuthbert, and D. V. Weseloh. 1999. Nesting populations of double-crested cormorants in the United States and Canada. Pages 17–25 *in* M. E. Tobin, editor. Symposium on double-crested cormorants: population status and management issues in the Midwest. U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Technical Bulletin 1879. Washington, D.C., USA.

U.S. Department of Agriculture. 2008. Catfish production. National Agricultural Statistics Service, Washington, D.C., USA.

U.S. Fish and Wildlife Service. 1998. Migratory bird permits: establishment of a depredation order for the double-crested cormorant (Final Rule), 50 CFR Part 21, RIN 1018-AE11. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C., USA.

Weseloh, D. V., and P. J. Ewins. 1994. Characteristics of a rapidly increasing colony of double-crested cormorants (*Phalacrocorax auritus*) in Lake Ontario: population size, reproductive parameters, and band recoveries. Journal of Great Lakes Research 20:443–456.

Weseloh, D. V., P. J. Ewins, J. Struger, P. Mineal, C. A. Bishop, S. Postupalsky, and J. P. Ludwig. 1995. Double-crested cormorants of the Great Lakes: changes in population size, breeding distribution and reproductive output between 1913 and 1991. Colonial Waterbirds 18:137–142.



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